# Expression of boron deficiency symptoms and link with the genotype in oil palm (*Elaeis guineensis* Jacq.)

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## Summary

Boron is an important trace element in the physiology of the oil palm. In the transport of carbohydrates, protein synthesis and energy transfer reaction, its deficiencies have spectacular effects. The deficiency occurs frequently in young trees, and in the most favourable ecologies in Indonesia in which the palms grow well.

In a fertiliser trial implemented at P.T. Socfindo Aek Loba Estate with 4 different progenies closely genetically linked, a new type of Boron deficiency symptom appeared very early. Mainly this affected only one of the four progenies where the Boron deficiency status was recorded regularly. In fact, 3 types of symptoms of Boron deficiency have been recorded. It appears that the expression of Boron deficiency symptoms derives more from the genotype affected than the level of the element in the leaf.

Observations recorded in commercial areas and in progeny trials, confirming the link between type of boron deficiency expression and genotype are also discussed.

**Keywords:** Oil Palm, *Elaeis guineensis* Jacq., Boron, mineral nutrition, Indonesia

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## 1. Introduction

The nutrient needed by the plant and the oil palm are classified in major elements, always presents in high proportion and the minor elements, of whom the level is low. The firsts are involved in the growth and the crop. The seconds are mainly implicated in specific but essential physiological processes (Jacquemard, 1998). Boron is recorded as micro – element for the oil palm as all other plants (Eschbach, 1980; Fairhurst and Härdler, 2003).

### a. Role of boron

Boron takes part in the transport of elementary carbohydrates, the synthesis of the proteins and the oxidative phosphorylation (Eschbach, 1980). The element is essential for the cellular division and growth, the nucleic acids synthesis, the integrity of the cellular membranes, the pollen germination and the growth of the pollinic tube (Corrado, 1992; Fairhurst and Härdler, 2003). The lack of boron induces, by polyphenol accumulation, the inhibition of the indol – acetic acid oxydase. The accumulation of IAA causes physiological disorders (Eschbach, 1980; Fairhurst and Härdler, 2003).

### b. Deficiency symptoms

The boron deficiency appears frequently in the favourable ecosystems where the production of vegetative matter is high. They are generally provisional (Corrado, 1992; Caliman et al, 1994; Jacquemard, 1998; Corley and Tinker, 2003). They are harder at immature stage and their intensity varies according the seasons (Corrado, 1992). The strong demand of the oil palm at specific periods appears inducing the deficiency more than the boron available in the soil (Eschbach, 1980). The risks increase where the soil content remains lower than 0.3 to 0.5 ppm (B extracted with hot water) (Corrado, 1992). Very acid or alkaline soils, heavy rainfall season are also potentially susceptible well known conditions (Fairhurst and Caliman, 2005). The oil palms planted on strongly developed soils like the Malaysian and Indonesian oxysoils could be affected by such deficiency without boron fertilisation (Fairhurst and Härdler, 2003). But, in oil palm cultivation, it remains complicate to attribute a specific soil type to the boron deficiency (Corley and Tinker, 2003).

The boron deficiency is disturbing the growth of the leaf from initial shape up to the meristem to the final stretching. The symptoms, visible as early as the spear apparition and the opening of the leaflets, induce irreversible deformation and discolouration of the leaf (Corrado, 1992).

The symptoms could be sorted within three classes:

- Smooth deformation of the leaflets inducing few or no reduction of the leaf area
- Important reduction of the leaf area without real modification of the leaf emission
- Disappearance of the lamina, rachis atrophy and strong reduction of the leaf emission

The symptoms regularly observed in the field are as follows (Rajaratnam, 1973; Corrado, 1992; Corley and Tinker, 2003; Fairhurst *et al*, 2005):

- Hooked leaflets
- Little leaf
- Chlorotic stripes
- Crinkled leaflets
- Fish bone leaf
- Atrophic leaf
- Atrophic rachis

At ultimate stage, the tree dies by necrosis of the apex.

The boron deficiency could be confused with the Spear Rot – like Syndrome induced by insect attacks like *Oryctes* or the Spear Rot – Little Leaf disease (Corley and Tinker, 2003) or possible genetic anomalies (Corrado, 1992).

### c. Nutrition

On seedlings cultivated on sand, some hierarchy of symptoms appears: chlorotic stripes become visible at 8 ppm, short leaves below 5 ppm and classical little leaf symptom around 2 ppm (Rajaratnam, 1973). On adult trees, the range of boron content in the leaf 17 is 5 to 20 ppm. It is lower than the other species (Eschbach, 1980). It seems that the symptoms of deficiency are appearing below 10 ppm only (Corrado, 1992).

High level of potassium could induce boron deficiency (Corrado, 1992). But symptoms of boron deficiency – like on young leaves (small white – yellow spots with limb deformation on dark green leaves) are recorded on young palms K0 in a mineral nutrition experiment in North – Sumatra (Tailliez, 1982). Excess in nitrogen fertilisation could induce boron deficiency and chlorotic stripes on leaflets (Fairhurst and Härdler, 2003).

Excess of boron induces chlorotic stripes on the leaflet tip. The chlorosis is developing quickly in necrosis from the distal part of the leaf to the proximal one (Fairhurst and Härdler, 2003).

The treatment of the boron deficiency needs application of borate fertilizer. Dose varies with the age of the trees (50 g of sodium borate / tree / year at 1 year old to 200 g / tree / year for full mature palms). To correct efficiently a severe deficiency, applications partly on ground and on the base of the medium crown is required (Fairhurst *et al*, 2005).

The severe boron deficiency has a strong effect on the crop that could down by 84%. This drop is probably caused by the drastic reduction of the leaf area and by metabolic changes also (Rajaratnam, 1973).

## 2. Material and method

### a. Localisation

The study has been done on a fertilizer experiment taking place at the division 5 from the Aek Loba Estate (PT Socfindo). This estate is located in the North Sumatra province at 220 km in the south of Medan. The climate is fairly humid with 2890 mm of annual rainfall, less than 30 mm of annual water deficit and 20 mm as rainfall intensity.

### b. Protocol

The experiment has been planted in October – November 2000 after a first generation of oil palm and covers more or less 17 ha. The aim of the trial is to follow the study of the interaction between the mineral nutrition and the genetic background of the planting material after being conspicuous in several progeny trials and fertilizer experiments (Jacquemard *et al*, 2002). Four progenies have been chosen in a preliminary experiment in nursery for their contrasted leaf content for potassium and magnesium.

The experiment studies their behaviour facing contrasted supplying in both elements and would try to establish if their critical levels differ. Until the end of N1, the trial received a fertilization according the commercial standard for Aek Loba Estate. Differentiated applications for potassium and magnesium occurred in April 2002. The nitrogen, phosphorus and boron requirements follow the commercial standard. The fertilization applied is summarized in annexe 1.

The statistical design is $2^4$ subdivided. The studied factors are:

4 levels of potassium (0, x, 2x, 3x)
4 levels of magnesium (0, x, 2x, 3x)

The subdivision is concerning the progenies (table 1). All of them are derived from (DA5D * DA3D) * LM2T selfed commercial material. The elementary plot includes 36 trees: 16 useful trees and 20 for bordure. The sub – elementary plot includes 2 * 2 trees.

Table 1: Sub – division

| No | Type | Code |
|---|---|---|
| A | K-Mg- | SL2422 |
| B | K-Mg+ | SL2421 |
| C | K+Mg- | SL2427 |
| D | K+Mg+ | SL2418 |

Primary observation includes regular census of possible morphological and flowering anomalies and an annual leaf sampling for the nutrition evaluation. Leaf sampling and analyse of mineral contents are done according the standard of IRHO (Martin, 1975; Ochs and Olivin, 1977 and Bonvalet, 1981).

## 3. Observation and results

Several individual censuses (once a trimester) have been done from the planting date to the end of 2003. The vegetative observation carried out put in evidence early symptoms of leaf reducing looking as boron deficiency and at more or less 2 years old extensive classical symptoms of boron deficiency.

### a. Precocious little leaf (P2L)

#### i. Description

The symptoms appear few weeks after planting (2 or 3 months). The affected trees are presenting the following aspect (fig 1 to fig 3):

Reduction of the growth
Drastic reduction of the length of the petiole and the rachis
Drastic reduction of the length of the leaflets
Limb remaining dark green

Stumping has not been recorded.

Figure 1: Affected tree

Figure 2: Normal tree

Figure 3: Affected tree

### ii. Data

The census has been realised from planting date to May 2002. P2L has been recorded on 61 trees (2.45 % out of 2484 planted trees) and 43 trees inside the trial (2.49 % out of 1728 trees).

The susceptibility of the 4 progenies used is very variable (Table 2). The most susceptible one, SL2427, shows quite 9 trees / ha affected by the disorder.

Table 2: Symptom of P2L per progeny

| Code | Progeny | P2L | Planted | P2L/ha |
|---|---|---|---|---|
| A | SL2422 | 4 | 432 | 1.32 |
| B | SL2421 | 2 | 432 | 0.66 |
| C | SL2427 | 27 | 432 | 8.94 |
| D | SL2418 | 10 | 432 | 3.31 |

27 out of these 43 P2L trees have been replaced to not endanger the future of the experiment. All remaining affected trees received an additional fertilisation of 40g of borate / tree.

## b. Classical deficiency symptoms

In September 2002, new symptoms of boron deficiency appeared. They had not recorded in June 2002. A complete census has been done in October 2002 and verified in February 2003. 5 different types of symptoms, well described in the literature (Corley and Tinker, 2003, Turner and Gillbanks, 2003; Fairhurst *et al*, 2005) have been identified: Little leaf, hook leaflet, crinkle leaflet, fishbone and white stripes.

### i. Description

Little leaf

The symptom is classically reported as shortened leaf that may have malformations or reduction in frond length leading to a typical "flat – top" appearance. In the present case, 3 gradations of symptoms have been recorded:

Type 1: Flat – toped palms (Figure 4)
Type 2: Visible reduction of the frond length

Figure 4: Flat – toped palm

Type 3: Severe little leaf with alteration of the morphology of the leaf (Figure 5)

Figure 5: Severe little leaf

Hook leaflet

The extremity of the leaflets, generally on the distal part of the leaf, is deformed like a hook or "Z" (Figure 6).

Figure 6: Hook leaflet

Crinkle leaflet

The extremity of the leaflets is presenting a typical corrugation (Figure 7). It must be mixed up with the genetically mark of crinkle leaflets on DA115D * LM2T derived material.

Figure 7: Crinkle leaflet

Fishbone

On this anomaly (Figure 8), the leaf is often reduced to its rachis with stiff leaflets more of less reduced to their rachis also. The length of the leaflets is reducing quickly presenting a general habit of the central bone of fish.

Figure 8: Fishbone

White stripes

The white stripes symptoms may have many origins (genetic, BSR, etc). In the present case, it is pale yellow – green stripes parallel to the rachis of the leaflet (Figure 9). They may affect few to more leaflets.

### ii. Data

1116 trees have been recorded with symptoms of boron deficiency (65%). 98 out of them present 2 associated symptoms (19 trees on SL2422, 20 trees on SL2421, 3 trees on SL2427 and 56 trees on SL2418) and 8 trees show 3 associated symptoms (1 tree on SL2421 and 7 trees on SL2418).

The table 3 summarises the data recorded.

Figure 9: White stripes

Table 3: Distribution according the type of symptoms (number of trees)

| Type | Progeny | Affected trees | % | Little leaf | Hook leaflet | White stripes | Crinkle leaflet | Fishbone |
|---|---|---|---|---|---|---|---|---|
| A | SL2422 | 287 | 66.4 | 73 | 140 | 87 | 4 | 2 |
| B | SL2421 | 369 | 85.4 | 8 | 38 | 335 | 10 | 0 |
| C | SL2427 | 147 | 34.0 | 110 | 23 | 13 | 2 | 0 |
| D | SL2418 | 315 | 72.9 | 62 | 211 | 33 | 74 | 6 |

The little leaf symptoms could be split in between the different types described above (table 4).

Table 4: Distribution of the little leaf symptoms (number of trees)

| Type | Progeny | Type I | Type II | Type III |
|---|---|---|---|---|
| A | SL2422 | 67 | 4 | 2 |
| B | SL2421 | 4 | 2 | 2 |
| C | SL2427 | 74 | 16 | 20 |
| D | SL2418 | 38 | 23 | 1 |

The different combinations of symptoms encountered are summarised in the table 5:

Table 5: Combinations of symptoms (number of cases)

| | Hook leaflet | White stripes | Crinkle leaflet | Fishbone |
|---|---|---|---|---|
| White stripes | 25 | | | |
| Crinkle leaflet | 36 | 3 | | |
| Fishbone | 6 | 0 | 1 | |
| Little leaf | 27 | 11 | 13 | 2 |

For the ANOVA, all data have been transformed by the formula y = Arcsin $\sqrt{(r+3/8)/(n+3/4)}$ where r = number of affected trees in the plot and n the number of trees planted in the plot (Anscombe, 1948 cited by de Franqueville, 1984).

The ANOVA indicates very significant differences between the progenies for all symptoms, except for the fishbone one (table 6).

Table 6: Values of the F test

| Type of symptoms | F | Probability |
|---|---|---|
| Little leaf | 15.323 | 0.00322 |
| Hook leaflet | 39.363 | 0.00024 |
| White stripes | 127.853 | 7.946E-06 |
| Crinkle leaflet | 28.379 | 0.00061 |
| Fishbone | 1.3872 | 0.33445 |

The corresponding frequencies are summarised in the tables 7 and 8. The fishbone data are omitted because the lack of significance.

Table 7: Frequencies of the symptoms in the progenies (trees / ha)

| Code | Progeny | Little leaf | Hook leaflet | White stripes | Crinkle leaflet |
|---|---|---|---|---|---|
| A | SL2422 | 24.2 | <u>46.3</u> | 28.8 | 1.3 |
| B | SL2421 | 2.3 | 10.9 | **<u>129.0</u>** | 0.9 |
| C | SL2427 | **<u>36.4</u>** | 7.6 | 4.3 | 0.7 |
| D | SL2418 | 20.9 | **<u>71.5</u>** | 7.9 | **26.8** |

Table 8: Frequencies in the progenies according the type of little leaf (%)

| Code | Progeny | Type I | Type II | Type III |
|---|---|---|---|---|
| A | SL2422 | <u>22.2</u> | 1.3 | 0.7 |
| B | SL2421 | <u>1.3</u> | 0.3 | 0.7 |
| C | SL2427 | **<u>24.5</u>** | 5.3 | **6.6** |
| D | SL2418 | <u>12.6</u> | **7.9** | 0.3 |

## 4. Discussion

### a. Relation between P2L and little leaf symptoms

The precocious little leaf (P2L) affects mostly SL2427 from where come 63 % of the total affected trees. 8.9 trees / ha show the symptoms. The February 2003 census confirms the susceptibility of the same progeny where 36.4

trees / ha show symptoms of little leaf. The frequency of type III (the strongest one) recorded in February 2003 is very significant compared to the other progenies.

### b. Expression of the symptoms according the genotype

According the tables 7 and 8, it is easy to address a type of symptom and a specific genotype.

#### i. Little leaf

SL2421 (B) looks quite exempt of symptoms of little leaf, compared to the other progenies. In these 3 other progenies, SL2427 (C) shows the largest proportion of Type I and Type III trees. The intermediate type (T II) is more present on SL2418.

#### ii. Hook leaflet

Hook leaflets are present on a large part of the trees from SL2418 and in a lower frequency on SL2422. Their level on the others remains lower than the critical one.

#### iii. White stripes

White stripes are the quite sole portion of SL2421. Only very few trees show such symptoms on the other progenies.

#### iv. Crinkle leaflet

Crinkle leaflets are present on SL2418 in very large majority. The number of effected trees on the other progenies is anecdotic.

Finally, the expression of boron deficiency symptoms appears specific to definite progenies: Crinkle and hook leaflets to SL2418, little leaf to SL2427, White stripes to SL2421.

### c. Relation with the mineral nutrition

Three series of information are available concerning the mineral nutrition. The first one is related with the nutritional level at the end of the nursery (Table 9), the second (Table 10) represents this nutritional level in September 2001. The table 11 compares the mineral status of normal trees and P2L trees.

Table 9: Status of mineral nutrition at the end of the nursery (F3)

| Code | Progeny | N% | P% | K% | Ca% | Mg% | B ppm |
|---|---|---|---|---|---|---|---|
| A | SL2422 | 3.75 | 0.216 | 1.810 | 0.452 | 0.213 | 9.8 |
| B | SL2421 | 3.87 | 0.222 | 1.739 | 0.492 | 0.278 | 10.6 |
| C | SL2427 | 3.68 | 0.216 | 1.903 | 0.432 | 0.270 | 10.1 |
| D | SL2418 | 3.78 | 0.216 | 1.909 | 0.313 | 0.209 | 10.2 |

Is it possible to detect the P2L susceptibility in the field from leaf nutritional status at the end of the nursery? In fact, the leaf content in boron appears very uniform between progenies. But, a significant negative correlation (r = -0.82*) is detected between the level in nitrogen in nursery and the frequency of P2L.

Table 10: Status of mineral nutrition in July 2001 (F9)

| Code | Progeny | N% | P% | K% | Ca% | Mg% | B ppm |
|---|---|---|---|---|---|---|---|
| A | SL2422 | 2.835 | 0.173 | 1.025 | 0.848 | 0.257 | 19.1 |
| B | SL2421 | 3.001 | 0.182 | 1.011 | 0.832 | 0.298 | 19.2 |
| C | SL2427 | 2.844 | 0.177 | 1.138 | 0.755 | 0.259 | 16.4 |
| D | SL2418 | 2.832 | 0.175 | 0.976 | 0.874 | 0.268 | 19.5 |

The mineral status of the progenies reported in the table 10 corresponds to this occurring where the peak of expression of symptoms was recorded. The general level in boron seems sufficiently high to avoid any boron deficiency. But, significant correlations are noted between P2L frequencies and the leaf content for boron (r = -0.91*) and potassium (r = 0.84*).

There is no evidence of relationship between the boron leaf content en September 2001 and the different symptoms of boron deficiency recorded in 2002.

Table 12: Status of mineral nutrition on P2L / normal trees in July 2001 (F9)

| Type | N% | P% | K% | Ca% | Mg% | B ppm |
|---|---|---|---|---|---|---|
| P2L | 3.353 | 0.199 | 1.190 | 0.840 | 0.288 | 27.2 |
| Normal | 2.984 | 0.178 | 1.024 | 0.775 | 0.262 | 22.1 |

The leaf contents of nitrogen, phosphorus, potassium are largely higher in the P2L trees than in the normal trees. The boron level is surprisingly higher also. But, it could be the consequence of the boron deficiency and not the cause. The very hard deformation of the leaves and the great disturbance of the growth could be an explanation.

The mineral status of the progenies in July 2003, more or less 6 months before the last census is summarised in the table 13.

Table 13: Status of mineral nutrition in July 2003 (F17)

| Code | Progeny | N% | P% | K% | Ca% | Mg% | B ppm |
|---|---|---|---|---|---|---|---|
| A | SL2422 | 3.039 | 0.171 | 1.000 | 0.925 | 0.230 | 17.8 |
| B | SL2421 | 3.083 | 0.171 | 0.882 | 0.978 | 0.268 | 18.2 |
| C | SL2427 | 2.962 | 0.172 | 1.129 | 0.871 | 0.256 | 17.6 |
| D | SL2418 | 2.988 | 0.170 | 0.947 | 0.949 | 0.245 | 17.8 |

The leaf content in boron is high and satisfactory, but the progeny presenting the highest frequency of little leaf by the end of 2003, SL2427, presents also the lowest level in boron on leaf.

SL2421 showing quite all the trees affected by the white stripes symptoms get also the highest level in nitrogen and in boron and the lowest in potassium.

At five years old, after regular applications of boron and some corrective ones on very affected trees (table 14), there is no more evidence of symptom of boron deficiency.

Table 14: Application of boron fertiliser (g / tree)

| Stage | Year | 1st semester | 2nd semester | Total |
|---|---|---|---|---|
| N1 | 2001 | 10 | 20 | 30 |
| N2 | 2002 | 40 | 50 | 90 |
| N3 | 2003 | 75 | 75 | 150 |
| N4 | 2004 | 75 | 75 | 150 |
| N5 | 2005 | 50 | 50 | 100 |

Extra application: N1: 20 g / tree; N2: 50 g / tree

## 5. Conclusion

In conclusion, the effect of the genetic combination seems important in the expression of the symptoms of the boron deficiency. The link with the level of boron in the leaf is clear for the P2L and little leaf symptoms. But this link should be considered at relative level not at absolute one.

The white stripes should be more linked with an improper balance of nutrients in the trees: high level of nitrogen and potassium in progeny like SL2421 could induce boron deficiency symptoms despite sufficient level of boron. On young mature trees, it is possible to record severe white stripes linked with partial or quasi total abortion of the bunch.

Hook leaflets cannot be correlated with any specific characteristic of the mineral nutrition. The effect of the genetic combination associated with a transitory incapacity to mobilise the boron appears to be the most probable. The same observation is possible for the crinkle leaflet symptoms.

There is no consistent evidence of gradation of gravity between the different types of symptoms. They appear to be the specific reaction of the genotype of the boron suffering.

Spotted and general applications of boron are sufficient to solve the problem. The P2L trees should recover without after - effects if they receive very early regular and adapted complement of boron application.

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